

Original Research Article

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Evaluation of Nutrient Expert Based Fertilizer Recommendation for Growth, Yield and Nutrient Uptake of Maize Hybrids and Soil Properties in Maize-Wheat Cropping System in Mollisol

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ABSTRACT

Maize is a heavy nutrient feeder crop but over and inappropriate fertilization provides lesser yield than the genetic yield potential, lower profits and deterioration in soil health therefore, a new fertilizer recommendation approach, Nutrient Expert (NE) for hybrid maize was evaluated against farmers fertilizer practice (FFP) in three years maize-wheat rotation. Results revealed that nutrient expert-decision support system based nutrient management gave higher yield, nutrient uptake and profits and sustained soil properties over other practices. Days recorded to 50% tassel and silk emergences with SSNM were lesser by 1.7 and 3.2 over 100% RDF and 2.2 and 4.1 over FFP, respectively, consequently reduced anthesis silking interval (ASI). Grain yield, net return, N, P and K uptake of maize were recorded 4.4-7.9, 8.3-15.4, 10.1-16.9, 4.3-8.1 and 12.8-15.3%, respectively, higher with NE over other nutrient management strategies. Of the maize hybrids, hybrid 'PMH-1' sustained superiority but remained at par with 'CNH-08-292'. Grain yield of succeeding wheat crop was recorded 192 and 332 kg ha⁻¹ higher with NE compared to that of 100% RDF and FFP, respectively, and proved beneficial residual effect of nutrients applied in maize crop. Fertilizer application based on NE gave more net return of ` 9,198 and ` 15,412 over 100% RDF and FFP, respectively, in maize-wheat rotation. Hybrid 'PMH-1' was found most economically viable for rotation. Organic carbon in NE rose by 0.07 and 0.13 units over 100% RDF and FFP, respectively, however fertilizer containing practices enhanced the level from 0.01-0.14 units over initial level. Nutrient expert significantly increased the availability of N and K while depleted available P. Nutrient expert led to increased 16.7-46.3, 3.6-15.4 and 3.2-16.7 per cent mineralization, residual and loss of N, respectively, as compared with 100% RDF and FFP however loss of N was higher with FFP over 100% RDF.

Keywords

Maize, Wheat, nutrient management, Nutrient expert, Farmers' fertilizer practice, Soil properties.

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Introduction

Increase in food, feed and industrial needs along with the shrinking resources will generate great pressure on grain production in the future. With the already limited opportunity of the resources, the needed increase in cereal production can be met by

intensifying production of wheat, rice, and maize to reach 70–80% of their potential yields (Dyson, 1999; Dobermann and Cassman, 2002). Adaptation of intensive cropping system in a fixed piece of land in a fixed time period by the farmers moreover

imbalance use of fertilizer led to deplete in fertility of soil. Many researches have shown that over fertilization by the farmers for the desire of higher crop yield led not only increase the cost of cultivation but also creates negative effect on the soil and atmospheric environment which became more and more serious problems in most of the countries.

Maize is the third most important crop after rice and wheat in the world with an average yield of about 5.0 t ha⁻¹. Currently, it is cultivated in over 9.2 million ha with 24.17 million tonnes production having an average productivity of 2.56 t ha⁻¹ (IIMR, 2015) contributes to more than half of the coarse cereal food grains production of the country. Being a multipurpose crop, market demand of maize especially for making industrial products, maize has become as a more competitive crop and therefore encouraging the farmers to grow to a large extent in last few years. Consequently this crop is rapidly emerging as a favourable component crop in the major cropping system in India. Being a heavy nutrient and water required crop, maize needs intensive management on these inputs. Increasing the cost of inputs especially fertilizers, site specific nutrient management (SSNM) in different crops is most effective way to the farmers to enhance crop productivity and sustaining soil fertility because it aims to supply required nutrients to a crop for a specific field or growing environment. Site-specific nutrient management gathered the informations from different scales to make field-specific decisions on various essential nutrients management. Initially SSNM, was developed for rice in Asia (Dobermann *et al.*, 2002; Dobermann and Witt, 2004) to increased grain yield and sustained soil fertility but also has been adapted for others cereal crops viz. maize and wheat in Asia and elsewhere. At present many tools have been using by

farmers for applying required nutrients on targeted crop and field. Nutrient expert (NE), a simple nutrient decision support tool can also be used to develop fertilizer recommendations on a farmers filed. Nutrient expert for hybrid maize is new, computer based decision support tools developed to assist local experts to quickly formulate fertilizer guidelines for tropical hybrid maize based on the principles of site-specific nutrient management (SSNM). Adopting NE-based field specific fertilizer recommendations a significant increase in fertilizer efficiency and productivity of maize can be achieved (Satyanarayana *et al.*, 2013).

Materials and Methods

The field experiment was conducted at the N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (29° N and 79.5° E, 243.8 m above msl) on permanent maize-wheat crop sequence during 2013-14, 2014-15 and 2015-16. The experiment was started with maize crop grown during *kharif* season of 2013. The centre falls in *Tarai* belt of northern India lies below the foothills of Himalayas under humid subtropical climate with an average annual rainfall of 1433 mm, of which, more than 85% received during June-September. Occasional rains occur during winter months also. The maximum temperature may go up to the 43⁰C in May and minimum below 2⁰C in January. The experimental soil is derived from the calcareous alluvium, and classified as silty clay loam hyperthermic *Aquic Hapludoll*. The soil was neutral in reaction (pH 7.2), low in salt content (0.18 dS m⁻¹) and available N (188.2 kg ha⁻¹), medium in organic carbon (0.71%) and available K (138.5 kg ha⁻¹) and high in available P (28.2 kg ha⁻¹). Fifteen treatments combinations having 3 nutrient management practices and 5 hybrids replicated thrice in a randomized

block design were taken during the experiment. To evaluate the yield response of SSNM using NE, fertilizers applied in farmers fertilizer practice (FFP) and state recommended dose of fertilizers (100% RDF) and control in *Tarai* region, the maize hybrids 'PMH-1', 'PMH-3', 'PMH-4', 'HQPM-1' and 'CMH 08-292' were used. The nutrient-management practices in maize crop were 100% RDF (120:60:40 kg ha⁻¹ N: P₂O₅:K₂O), SSNM ('PMH-1', 'PMH-3', 'PMH-4' and 'CMH-08-292' 140:37:71 kg ha⁻¹ N:P₂O₅:K₂O), and for 'HQPM- 1' (120:33:46 kg ha⁻¹ N:P₂O₅:K₂O), farmers fertilizer practice (FFP) (93:64:32 kg ha⁻¹ N: P₂O₅:K₂O) and control (no nutrients). The fertilizer doses for SSNM were estimated using soil testing values and targeted yield of different hybrids through Nutrient Expert (NE) software (He *et al.*, 2009) developed and validated by International Plant Nutrition Institute (IPNI). Fertilizer doses for FFP were estimated by averaging N, P and K fertilizers used by 50 randomly selected farmers of the *Tarai* area. In the subsequent wheat crop, nutrients were applied as state recommendation (120:60:40 kg ha⁻¹ N: P₂O₅:K₂O) in all plots.

For the crops growth study in maize, five plants were randomly selected from each plot and plant height was measured at the harvest. Days from planting to anthesis and silking were estimated by regular observation up to the initiation of anthesis and emergence of silk in at least 50% of plants in each plot. Grain yield of crops in each plot was recorded at 15% moisture content on a dry weight basis and then yield per hectare was calculated. Soil samples were collected from 0-15 cm depth after completion of one crop rotation (after harvesting of wheat crop) and were analyzed for soil reaction (pH), organic C, available N, P and K and N dynamics. Nitrogen dynamics in the soil (0-60 cm depth) such as mineralization, loss and residual amounts for

N in the different nutrient management practices following equations (Zhao *et al.*, 2006) were used.

$$\text{Mineralization}_{(N)} = \text{uptake}_{(N)} + \text{residual}_{(N)} - \text{initial}_{(N)} \quad (1)$$

$$\text{Loss}_{(N)} = \text{mineralization}_{(N)} + \text{fertilizer}_{(N)} + \text{initial}_{(N)} - \text{uptake}_{(N)} - \text{residual}_{(N)} \quad (2)$$

Statistical analysis of data was carried out following the techniques of analysis of variance prescribed for factorial randomized block design (Gomez and Gomes, 1984) on standard computer programs developed by department of Mathematics, Statistics and Computer Science, college of basic sciences and humanities, G. B. Pant University of Agriculture and Technology, Pantnagar. Means were tested at 5 % level of probability wherever 'F' test was found significant.

Results and Discussion

Effect on maize

Site specific nutrient management through NE-based fertilizer application recorded significantly higher plant height of maize over FFP and control practices however was found statistically at par with state recommended dose of fertilizers (Table 1). It evident that nutrient dose provided by NE practice fulfills the nutrient requirement of the crop when required hence better plant height was obtained. Among the maize hybrids, hybrid 'PMH-1' gave significantly higher (187.7 cm) plant height over others except 'CMH-08-292' while 'PMH-4' attained significantly lowest plant height. Yield attributing characters viz., days to 50% tassel and silk emergence and weight of 100 grains were found to be significantly affected by nutrient management practices however different hybrids significantly affect 100 grains weight only. Weight of 100 grains was significantly

higher in SSNM through NE over FFP and control but remained at par with 100% RDF. Days recorded to 50% tassel and silk emergences with SSNM were lesser by 1.7 and 3.2 over 100% RDF and 2.2 and 4.1 over FFP, respectively, which indicate that NE-based SSNM reduced the tassel and silk emergence as well as anthesis silking interval (ASI). On the other hand control enhanced days to 50% tassel and silk emergence over practices. With respect to maize hybrids, lowest and highest ASI was recorded with 'PMH-1' (3.8 days) and 'PMH-4' (5.6 days), respectively. Extend in length of ASI resulted in poor pollination which in term affected the overall grain production (Lone and Warsi 2009). Similarly enhancement in growth attributes lead to photosynthates partitioning and better source-sink relationship, which enhances yield attributes. Kumar *et al.*, (2014) also confirmed similar findings in maize. The nutrient management practices resulted significant differences in grain as well as in stover yields. Averaging data for three years, results showed that highest grain yield was obtained with NE-based nutrient management (5825 kg ha⁻¹) strategy followed by 100% RDF (5348 kg ha⁻¹) and FFP (4772 kg ha⁻¹). Similarly different hybrids also produced significantly different grain and stover yields. Grain yield difference was found to be higher within nutrient management strategies compared within hybrids which indicate that grain yield responded more to variation in fertilizer doses than variation in hybrids. The higher yield with the NE-based SSNM might be due to that the NE-based NPK recommendation increased N and K use from 0-50.5 and 15.0-121.9%, respectively, while decreased P use from 38.3-48.4% over other nutrient management practices suggesting a right rate of nutrients sufficient to meet the attainable yield for different maize hybrids as well as optimizing nutrient use through appropriate changes in fertilizer dose. On the other hand, imbalance nutrient applications in

FFP probably the main reason for lower grain yield. Net return averaged over the years significantly influenced by nutrient management practices and hybrids. Compared with state recommendation (100% RDF) and FFP, NE-based fertilizer recommendation significantly increased grain yields by 478 kg ha⁻¹ and 1054 kg ha⁻¹ and net return by ` 6461.0 and ` 10,678.0, respectively. Sapkota *et al.*, (2014) in wheat and Pampolino *et al.*, (2012) and Satyanarayana *et al.*, (2013) in maize also reported higher grain yield and net return from NE-based fertilizer recommendation over others practices of fertilizer application. Highest total N, P and K uptake by crop was observed with nutrient expert and was higher by 13.8, 22.6 and 6.6 % over 100% RDF and by 27.9, 40.3 and 13.0 % over FFP, respectively. The higher nutrient uptake was due to higher N, P and K content as well as higher grain and stover yields where fertilizers were applied based on nutrient expert (Kumar *et al.*, 2014). Potassium uptake in FFP did not enhanced significantly over control where no K was applied. This might be due to sufficient K supply from the K dominant clay mineral i.e. illite of experimental soil. Moreover increasing the amount of K fertilizer from FFP (32 kg ha⁻¹) to 100% RDF (40 kg ha⁻¹) over control and from 100% RDF (40kg ha⁻¹) to NE (46-71 kg ha⁻¹) over FFP, response to K uptake was noticed. Among the hybrids, 'PMH-1' and 'HPQM-1' showed highest and lowest nutrient uptake, respectively, however nutrient uptake between some hybrids was statistically at par.

Effect on wheat

Nutrient management practices and maize hybrids also had significant effect on growth and yield attributes of subsequent wheat crop (Table 2). Nutrient management through SSNM practice resulted significantly higher plant height of 2.2 and 5.2 cm, effective tillers

of 10.7 and 19.5 m² and spike length of 0.20 and 0.51 cm over 100%RDF and FFP, respectively. Irrespective of applied equal amount of fertilizers in all nutrient management practices in wheat, the averaged grain and straw yields for three years were recorded higher with NE-based SSNM strategy and found in general significantly differed between nutrient management practices. Grain yield of wheat enhanced by 192 and 332 kg/ha in the plot receiving fertilizer based on nutrient expert tool as compared to state recommendation and farmers fertilizer practice, respectively, in the maize crop. This clearly showed the nutrients applied in SSNM practice in maize crop had the more residual effect on wheat than other fertilizer managed practices which could be attributed to greater effective tillers and larger spike length. Hybrid 'PMH-1' grown plot had highest grain yield of wheat compared to other hybrids which could be attributed to more inclusion of organic matter by residue of maize. Net returns and B: C ratio significantly differed among different nutrient management practices. Highest return of ` 35538 with B: C ratio 1.21 was obtained with NE based fertilizer application whereas control gave least which was at par with FFP. The total cost of cultivation in different nutrient management practices was similar therefore; lower grain yields in 100% RDF and FFP were mainly responsible for lesser net return as compared to NE-based nutrient management (Sapkota *et al.*, 2014). Higher above ground biomass resulted higher uptake of N, P and K under SSNM practice however P uptake remained at par with state recommendation. Net return and B: C ratio were observed significantly higher in 'PMH-1' but trends was noted similar to grain and straw yields. Nitrogen and K uptake by wheat was significantly affected with the variation in hybrids grown however P uptake varied non-significantly.

Effect on maize-wheat system

Averaging the three years cost of cultivation for maize-wheat system, NE-based fertilizer recommendation comprised significantly higher cost of cultivation over farmers' fertilizer practice but remained almost at par with state recommended fertilizer application (100%RDF) (Table 3). On the contrary, NE-based SSNM practice yielded significantly higher net return and B: C ratio and the differences in net return obtained in SSNM (` 15,412) was much higher than 100% RDF (` 6,214) compared with FFP. The higher gross and net returns in NE-based fertilizer application could be attributed to the higher grain yields of maize and wheat in all three years. Compared with absolute control, NE, 100% RDF and FFP increased net return by ` 21437, 12239 and 6214, respectively. Of the different hybrids, 'PMH-1' gave more net return varied from ` 3,342-13,584 over others. This clearly showed that higher yield potential of 'PMH-1' proved better net return. In spite of received same cost of cultivation in all hybrids except 'HQPM-1', noticeable differences in net return were obtained between hybrids however 'PMH-3' and 'PMH-4' produced at par profitability. Nutrient expert removed significantly higher N, P and K by 34.7, 8.0 and 12.8 kg ha⁻¹ and 60.9, 12.7 and 18.3 kg ha⁻¹ over 100% RDF and FFP, respectively. However, absolute control removed 16.8-77.7, 2.1-14.8 and 1.1-19.4 kg ha⁻¹ less N, P and K respectively, as compared to other practices. The higher nutrients uptake with NE-based fertilizer application practice was due to higher grain and biological yield of the system. Amongst hybrids, hybrid 'PMH-1' removed more nutrients however less variation in nutrients removal among the hybrids was obtained.

Table.1 Effect of nutrient management practices and maize hybrids on growth, yield attributes, yield and nutrient uptake by maize (mean over 3 years)

Treatment	Plant height (cm)	Days to 50% tasseling	Days to 50% silking	Plant stand (000 ⁷ /ha)	100 grain wt (g)	Stover yield (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	Net return (₹)	B: C ratio	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)
<i>Nutrient management practices</i>												
Control	172.6	55.5	59.2	81.9	27.98	6735	4217	35996	1.84	168.4	27.9	40.8
SSNM-NE	190.5	53.0	56.7	82.2	30.71	8383	5825	51516	2.04	231.5	40.7	48.7
100% RDF	186.2	52.6	56.5	82.3	30.26	7877	5348	45055	1.77	203.4	33.2	45.7
FFP	178.5	54.4	58.6	82.1	29.00	7179	4772	40839	1.85	181.0	29.0	43.1
SEm±	1.23	0.29	0.42	0.29	0.418	45.3	31.9	420.8	0.018	3.05	0.85	1.17
CD (0.05)	3.53	0.83	1.20	NS	1.196	129.8	91.4	1204.7	0.051	8.73	2.43	3.35
<i>Maize hybrids</i>												
PMH-1	187.7	53.8	57.6	82.4	31.08	8016	5323	47019	2.03	209.3	34.7	48.1
PMH-3	182.8	54.6	58.7	81.8	27.97	7353	5063	43595	1.88	191.8	32.2	42.8
HQPM-1	179.3	53.3	57.3	81.9	27.69	7171	4703	39142	1.71	184.1	30.3	38.8
PMH-4	176.2	53.7	57.1	81.9	30.05	7386	4944	42020	1.82	192.7	32.5	45.7
CMH-08-292	184.0	54.0	58.1	82.4	30.64	7791	5168	44981	1.94	202.4	33.7	47.5
SEm±	1.38	0.32	0.47	0.33	0.467	50.7	35.7	470.5	0.019	3.41	0.85	1.31
CD (0.05)	3.94	NS	NS	NS	1.337	145.1	102.2	1346.9	0.057	9.76	2.43	3.75

SSNM-NE: Site specific nutrient management-nutrient expert, RDF: Recommended dose of fertilizers, FFP: Farmers fertilizer practice, NS: Non significant

Table.2 Effect of nutrient management practices and maize hybrids on growth, yield attributes, yield and nutrient uptake by wheat (mean over 3 years)

Treatment	Plant height (cm)	Effective tillers m ⁻²	Spike length (cm)	Straw yield (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	Net return (₹)	B: C ratio	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)
<i>Nutrient management practices</i>										
Control	89.4	355.2	7.76	7834	4136	29622	1.01	57.3	12.7	73.9
SSNM-NE	98.0	378.0	8.39	8460	4551	35538	1.21	72.1	14.7	86.6
100% RDF	95.8	367.3	8.19	8213	4359	32802	1.12	65.5	14.1	76.8
FFP	92.8	358.5	7.88	8059	4219	30805	1.05	61.7	13.6	75.1
SEm±	0.29	2.93	0.06	37.1	32.4	461.8	0.002	0.70	0.21	0.74
CD (0.05)	0.84	8.40	0.18	106.3	92.8	1322.1	0.045	2.00	0.59	2.12
<i>Maize hybrids</i>										
PMH-1	95.6	378.1	8.38	8343	4507	34908	1.19	64.9	14.0	79.8
PMH-3	94.2	359.8	8.08	8191	4279	31670	1.08	65.1	13.6	79.3
HQPM-1	91.8	351.5	7.71	7913	4106	29201	1.00	62.1	13.8	73.5
PMH-4	93.4	363.3	7.93	8044	4273	31576	1.08	63.1	13.8	80.0
CMH-08-292	95.0	371.3	8.15	8216	4415	33604	1.15	65.7	13.5	77.9
SEm±	0.33	3.28	0.07	41.5	36.2	516.3	0.017	0.78	0.23	0.82
CD (0.05)	0.94	9.39	0.20	118.8	103.8	1478.1	0.051	2.23	NS	2.37

SSNM-NE: Site specific nutrient management-nutrient expert, RDF: Recommended dose of fertilizers, FFP: Farmers fertilizer practice, NS: Non significant

Table.3 Effect of nutrient management practices and maize hybrids on economics and nutrient uptake by maize-wheat system (mean over 3 years)

Treatment	Cost of cultivation (₹)	Net return (₹)	B: C ratio	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)
<i>Nutrient management practices</i>						
Control	48893	65618	1.34	225.9	40.5	115.9
SSNM-NE	54573	87055	1.60	303.6	55.3	135.3
100% RDF	54737	77857	1.42	268.9	47.3	122.5
FFP	51365	71643	1.40	242.7	42.6	117.0
SEm±	11.5	598.0	0.001	3.15	0.86	1.38
CD (0.05)	32.9	1711.9	0.003	9.02	2.47	3.94
<i>Maize hybrids</i>						
PMH-1	52450	81927	1.56	274.2	48.7	127.9
PMH-3	52450	75265	1.43	256.9	45.8	122.0
HQPM-1	52162	68343	1.31	246.2	44.2	112.3
PMH-4	52449	73596	1.40	255.9	46.4	125.8
CMH-08-292	52449	78585	1.50	268.2	47.2	125.4
SEm±	12.9	668.5	0.013	3.52	0.97	1.54
CD (0.05)	36.8	1914.0	0.036	10.09	2.76	4.41

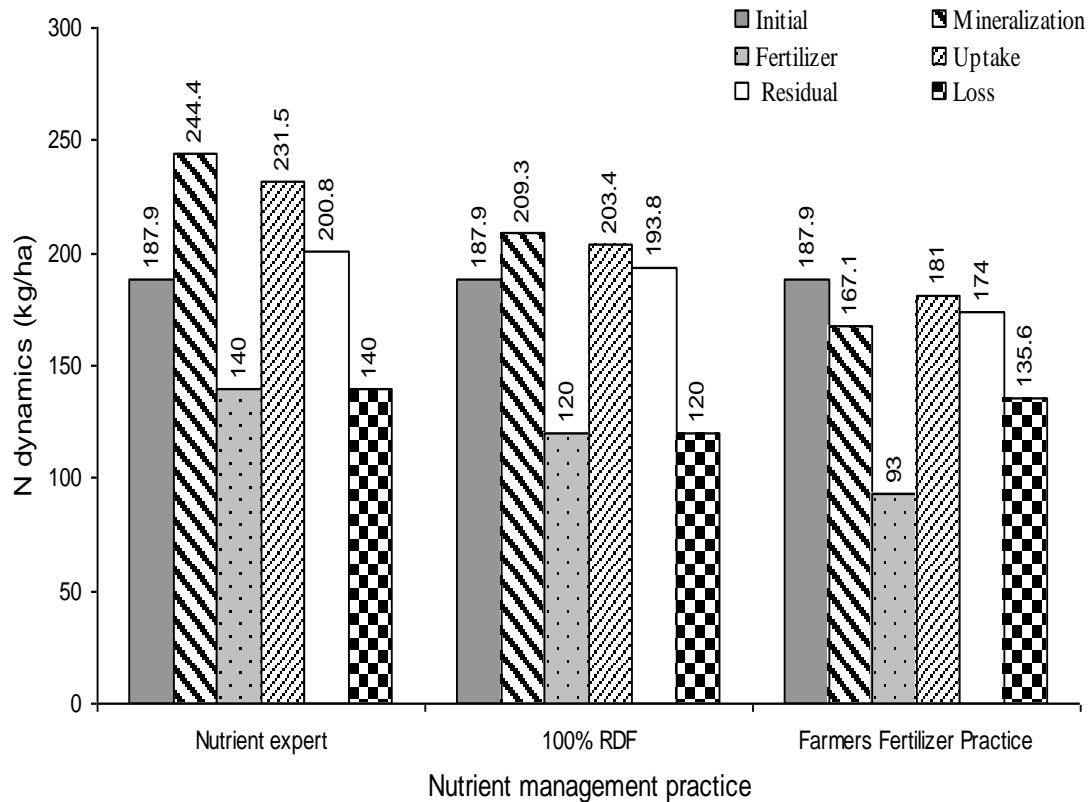
SSNM-NE: Site specific nutrient management-nutrient expert, RDF: Recommended dose of fertilizers, FFP: Farmers fertilizer practice

Table.4 Effect of nutrient management practices and maize hybrids on soil properties (mean over 3 years)

Treatment	Soil pH	Organic C (%)	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)
<i>Nutrient management practices</i>					
Control	7.03	0.66	176.2	23.4	131.3
SSNM-NE	7.11	0.85	202.5	26.4	146.7
100% RDF	7.16	0.78	190.9	30.8	138.6
FFP	7.14	0.72	183.0	30.5	136.5
SEm±	0.019	0.008	0.81	0.36	0.71
CD (0.05)	0.056	0.022	2.33	1.06	2.03
<i>Maize hybrids</i>					
PMH-1	7.07	0.77	187.8	27.8	141.3
PMH-3	7.11	0.75	189.6	27.8	140.4
HQPM-1	7.15	0.73	184.2	28.3	129.7
PMH-4	7.10	0.74	189.7	27.8	138.8
CMH-08-292	7.12	0.76	189.4	27.0	141.3
SEm±	0.022	0.009	0.91	0.41	0.79
CD (0.05)	0.062	0.024	2.60	NS	2.27

SSNM-NE: Site specific nutrient management-nutrient expert, RDF: Recommended dose of fertilizers, FFP: Farmers fertilizer practice, NS: Non significant

Fig.1 Nitrogen dynamics in Nutrient Expert, 100% RDF and Farmer’s Fertilizer Practice for the maize crop



Results for nutrient uptake were in conformity with the finding of Kumar *et al.*, (2014) for nutrient management practices and maize hybrids.

Effect on soil properties

The soil properties after three years of maize-wheat crop rotation varied significantly owing to change in fertilizer application strategies and hybrids (Table 4). Results showed that all the fertilizer management practices and hybrids brought the soil towards slightly acidic manner compared with initial level (7.2) however application of state recommended fertilizer dose maintained pH more close to initial level. Maximum depletion in pH level was obtained with

control. Similarly hybrid ‘PMH-1’ depleted pH highest. The management practices where fertilizers were added enhanced the organic carbon level from 0.01-0.14 units over initial level of 0.71 per cent however fertilizer applied based on nutrient expert tool rose the level more. The organic carbon in NE found to be rose by 0.13 and 0.07 units over FFP and 100% RDF, respectively. This could be attributed to higher plant growth and more addition of crop residue in soil resulting more organic matter production (Singh *et al.*, 2011). But very slight differences in organic carbon were noted among the hybrids. Use of higher dose of N and K fertilizers in NE and P in FFP and 100% RDF compared with other practices increased the available N, P and K however absolute control accelerated

depletion of availability of nutrients in soil over their initial levels. On the other hand, availability of N rose by 14.3 and 2.7 kg ha⁻¹, K by 8.2 and 0.1 kg ha⁻¹ in NE and 100% RDF, respectively, and availability of P by 2.6 and 2.3 kg/ha in 100% RDF and FFP, respectively, over their initial levels. Compared with FFP, NE increased availability of N and K by 10.7 and 7.5 per cent, respectively, while depletion in availability of P was observed by 13.4 per cent. In case of hybrids, availability of N and K was found to be increased in few hybrids grown plots however P availability decreased in almost all hybrid plots over initial level.

Effect on nutrient balance

Nitrogen balance obtained for maize after three years in maize-wheat crop rotation showed remarkable variation among NE, 100% RDF and FFP management practices (Fig. 1). Results revealed that mineralization, uptake, residual and loss of N were higher in NE compared with 100% RDF and FFP. Considering initial level of N, NE practice led to 16.8 and 3.6, 16.7 and 46.3 and 15.4 and 3.2 per cent higher mineralization, residual and loss of N over 100% RDF and FFP, respectively.

However 100% RDF recorded 25.3 and 11.4 per cent higher mineralization and residual N, respectively, and 11.5 per cent less loss of N over FFP. This indicates that higher residual and loss of N under NE would lead to more environment pollution by leaching and volatilization process etc. The mineralization, uptake and residual N were found in the order of NE>100RDF>FFP indicating that increase in N containing fertilizer led to more loss of N. Nevertheless FFP with less N dose showed more N loss over 100% RDF which probably due to application of N fertilizer apart from real time N requirement of crop. But Xu *et al.*, (2014) noted lower N loss under NE

compared with FFP in summer and spring maize using one third more N fertilizer in FFP.

In conclusion, based on results obtained for maize and wheat in three years crop rotation under different nutrient management practices it may be concluded that N, P and K fertilizers application in maize crop based on nutrient expert tool will increase the nutrient uptake and yield of maize and wheat and give more net return over state recommendation and farmers fertilizer practice. Maize hybrid 'PMH-1' may be best suitable under different nutrient management practices. Fertilizer application based on nutrient expert will maintain the organic carbon level higher as compared to other practices by incorporating the more crop residue in soil however more N loss may lead to soil and environment pollution. Fertilizer application with nutrient expert in maize crop in maize-wheat rotation may be a promising tool in *Tarai* soil over other nutrient management practices.

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